Low Energy Ion Accelerator
(LOI 64)

Paul Vetter, Damon Todd, Reina Maruyama,
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Lawrence Berkeley National Laboratory

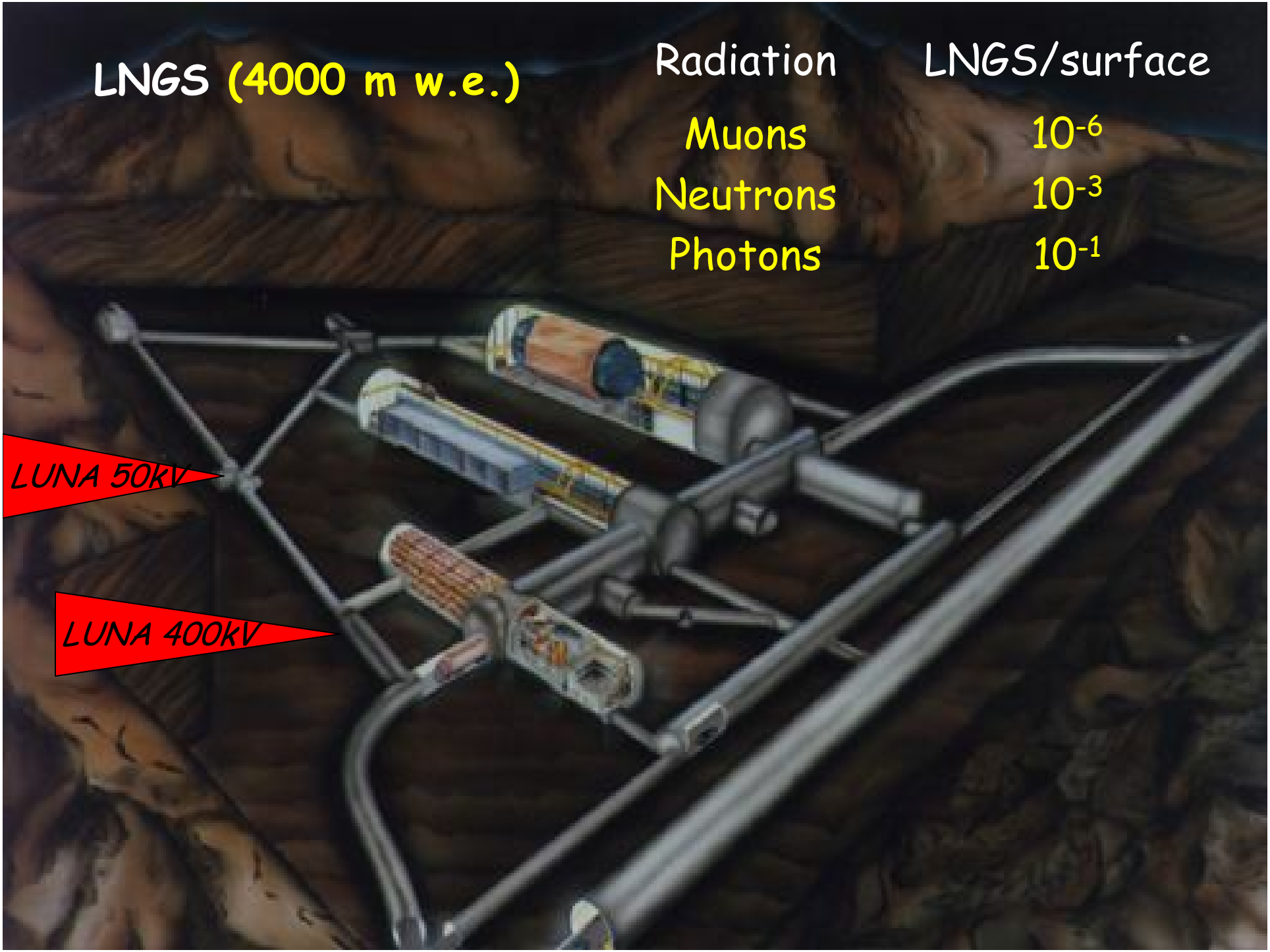
Lead WS FEB 8-10, 2006

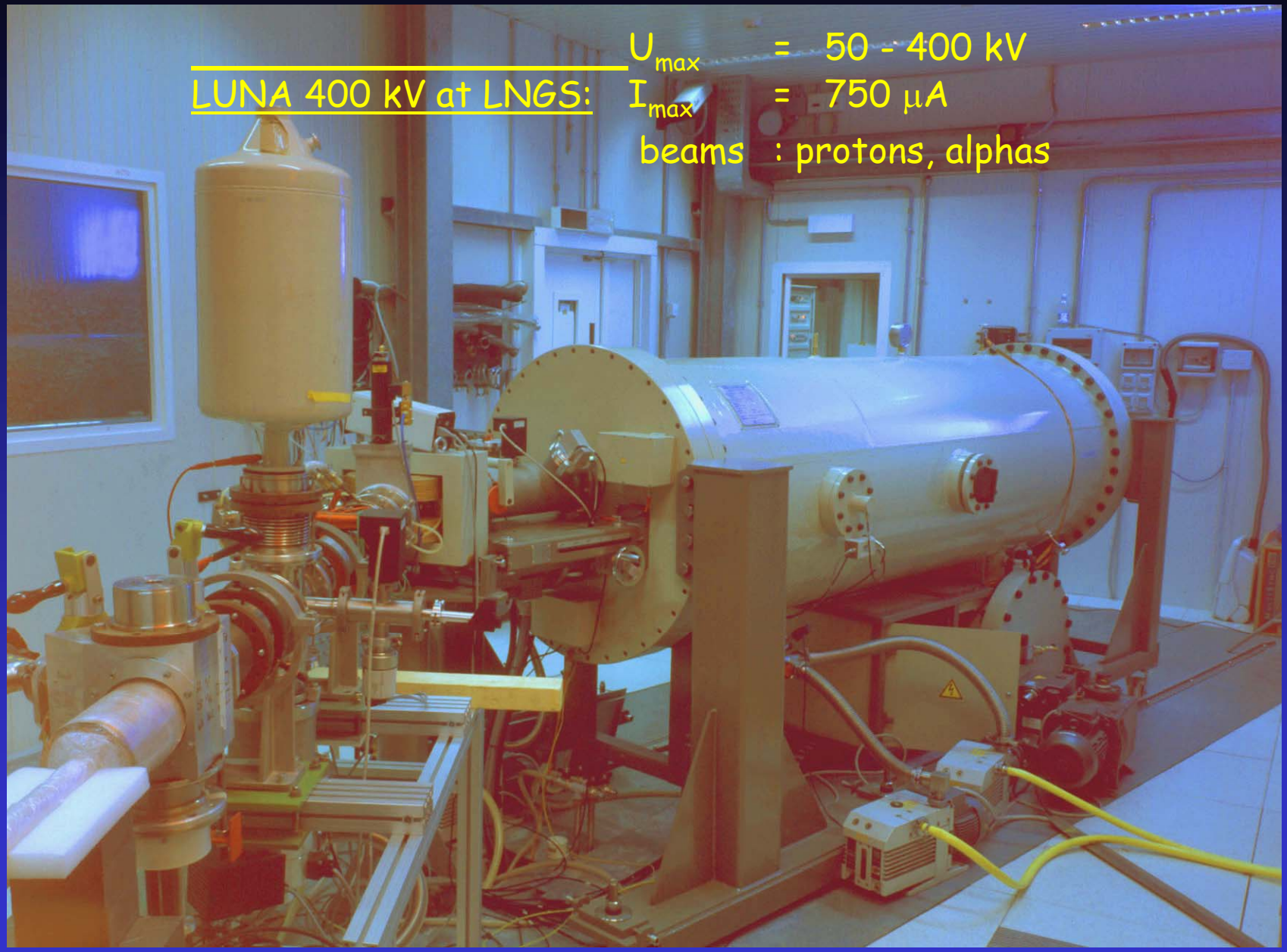
Greetings from the Moon...

Laboratory
Underground
Nuclear
Astrophysics

Paolo Prati
INFN - Genoa

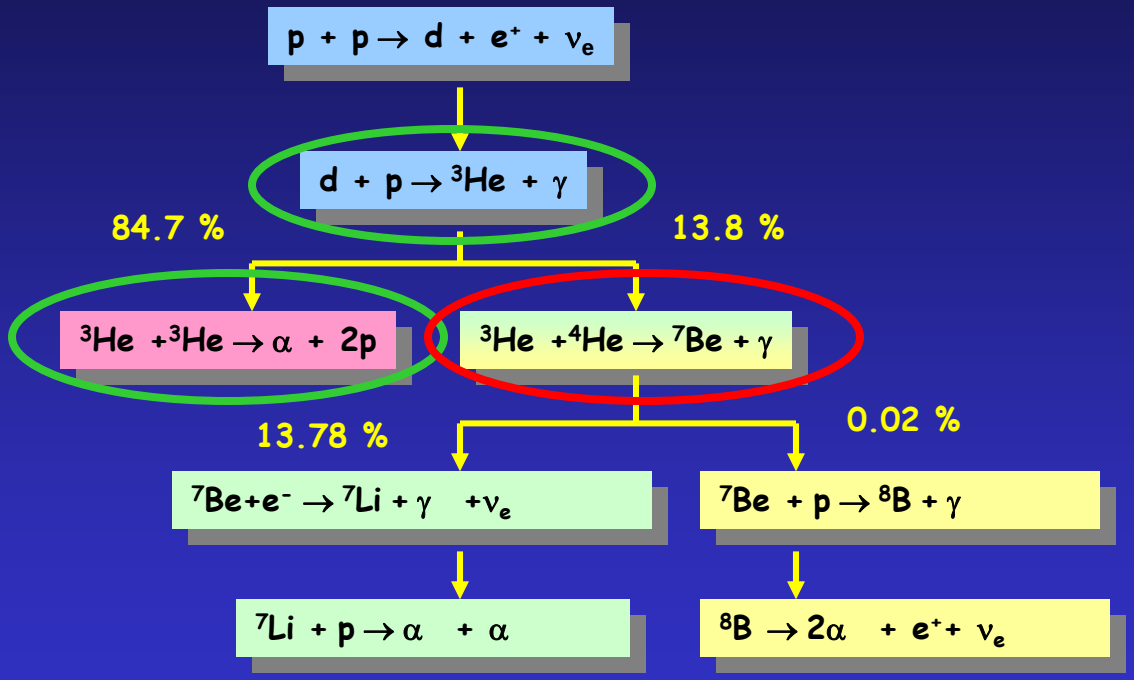
Lead Feb. 10th, 2006


LNGS (4000 m w.e.)
Radiation
LNGS/surface
Muons
10^{-6}
Neutrons
10^{-3}
Photons
10^{-1}
LUNA 50kV
LUNA 400kV

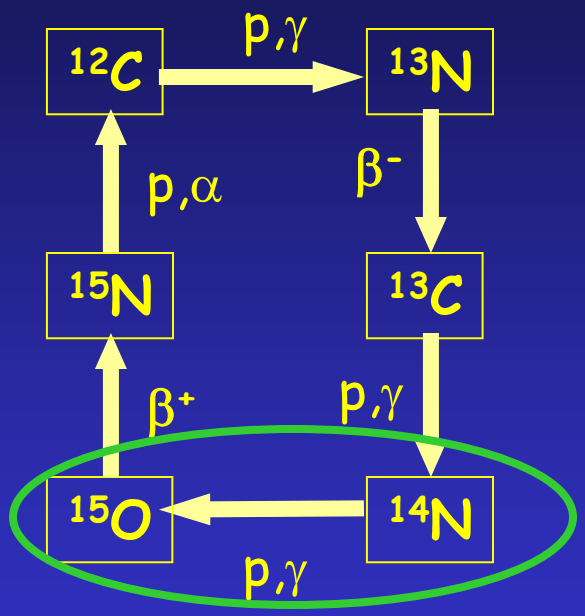

LUNA 400 kV at LNGS:
U_{max} = 50 - 400 kV
I_{max} = 750 μA
beams : protons, alphas

LUNA scientific program (past and present)

pp chain



CNO cycle



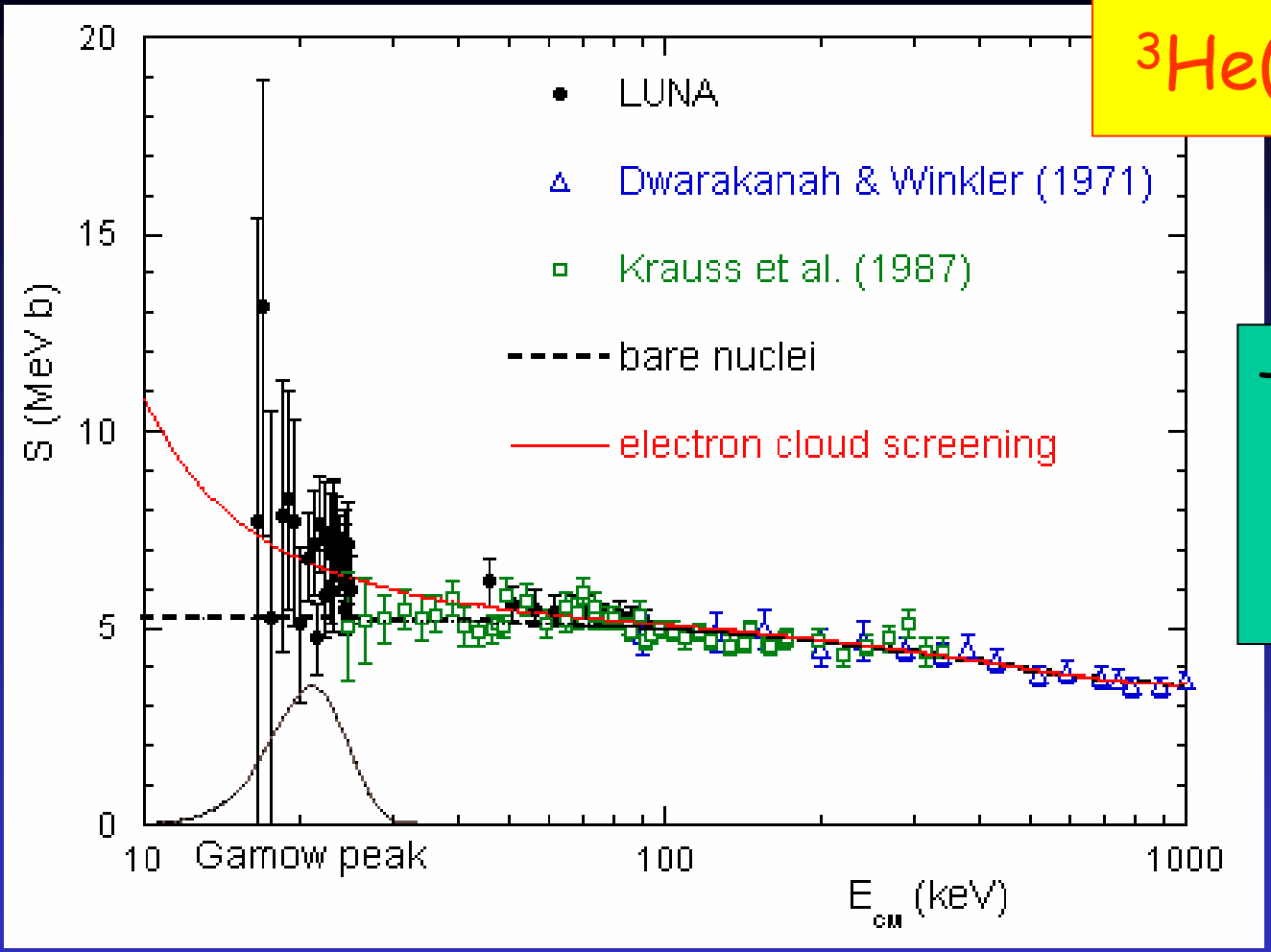
^{3}He(^{3}He,2p)^{4}He

d(p,γ)^{3}He

^{14}N(p,γ)^{15}O

^{3}He(^{4}He,γ)^{7}Be

$^3He(^3He,2p)^4He$



The first reaction studied inside the Gamow peak

count rate @ lowest energy: 2cts/month

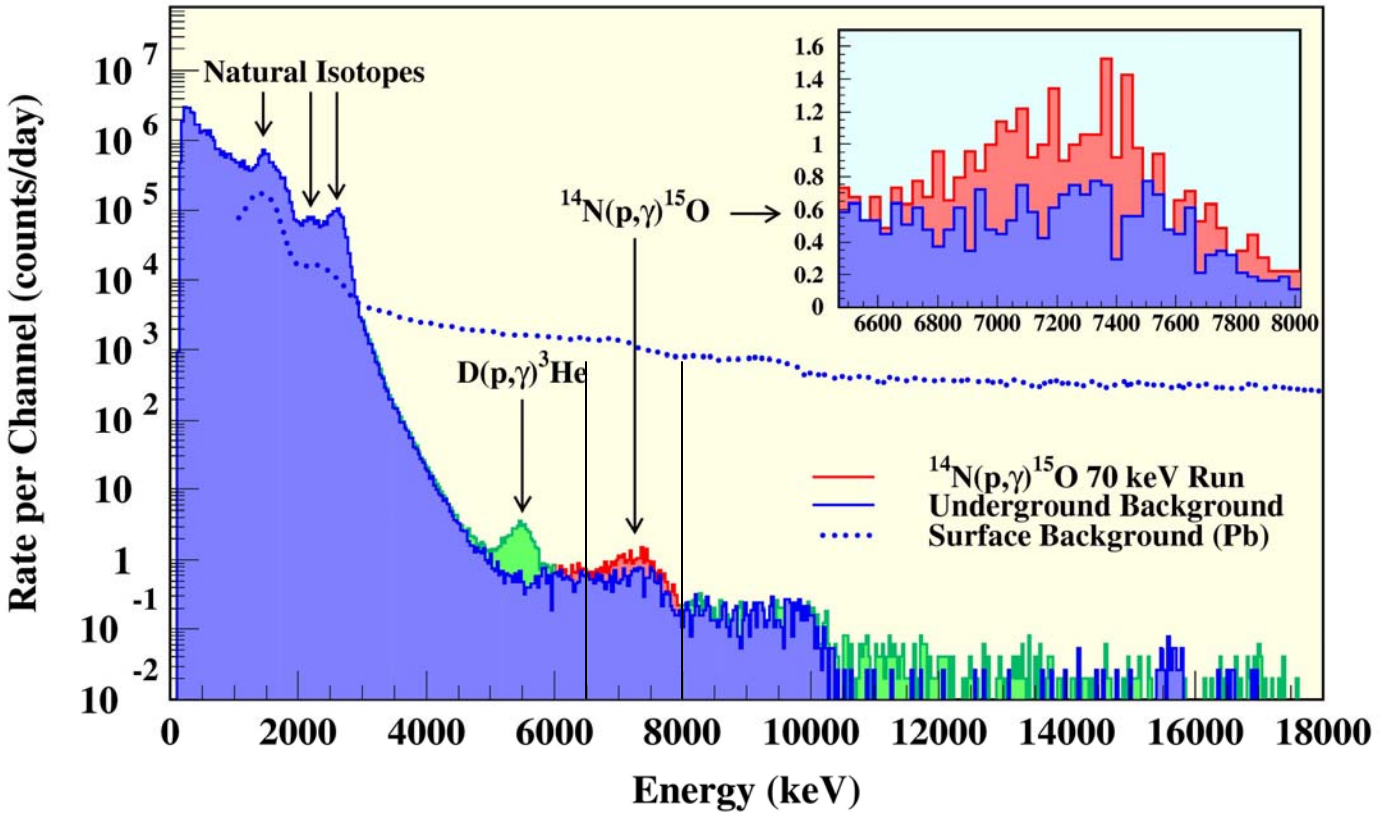
lowest cross section: 0.02 pbarn

background < $4*10^{-2}$ cts/d in ROI

$^{14}N(p,\gamma)^{15}O$ BGO Spectrum at E_{cm} = 70 keV

Q = 927±7 C

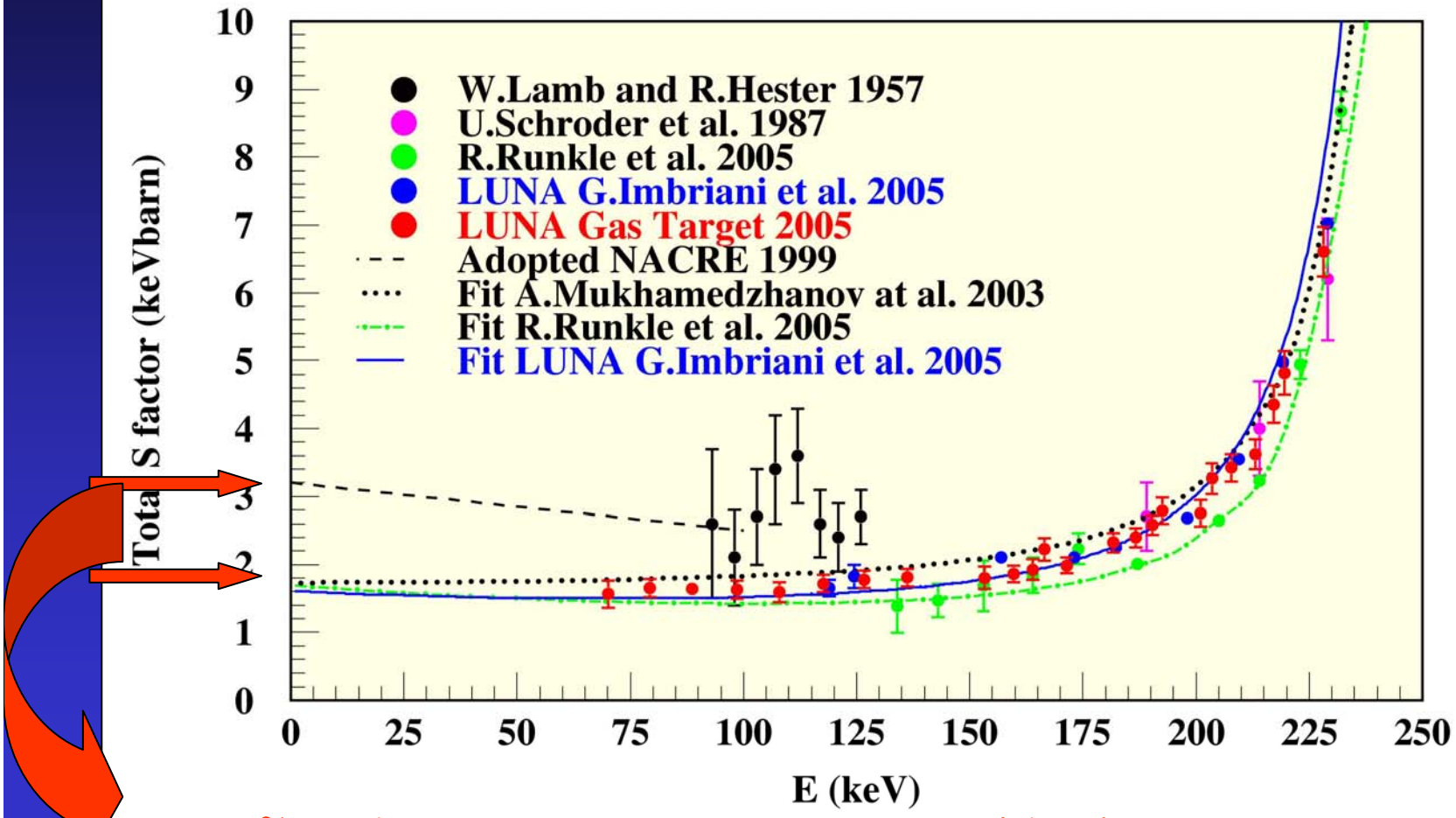
Δt = 49.12 days



Reaction Rate = 10.95 ± 0.83 counts/day
Background rate = 21.14 ± 0.75 counts/day

$^{14}N(p,\gamma)^{15}O$: total S- factor

A. Lemut et al., Phys. Lett B (2006), in press



50% reduction → Universe 1 Gyear older !

LUNA: future with the 400 kV facility and even more...

reaction	Q- value (MeV)	Gamow energy (keV)	Lowest meas. Energy (keV)	LUNA limit (keV, estimate)
$^{12}C(\alpha,\gamma)^{16}O$	7.16	300	950	500
$^{22}Ne(\alpha,n)^{25}Mg$	-0.47	470-700	850	630
$^{13}C(\alpha,n)^{16}O$	2.21	170-250	270	200
$^{2}H(\alpha,\gamma)^{6}Li$	1.47	50-300	700 (direct) 50 (indirect)	50
$^{15}N(p,\gamma)^{16}O$	12.13	10-300	130	50
$^{17}O(p,\gamma)^{18}F$	5.6	35-260	300	65
$^{18}O(p,\gamma)^{19}F$	8.0	50-200	143	143
$^{23}Na(p,\gamma)^{24}Mg$	11.7	100-200	240	138
$^{22}Ne(p,\gamma)^{23}Na$	8.8	50-300	250	68
$^{15}N(\alpha,\gamma)^{19}F$	4.01	364	536	364

Red: feasible at LUNA2; Blue: LUNA3 required, Green: LUNA3 desireable

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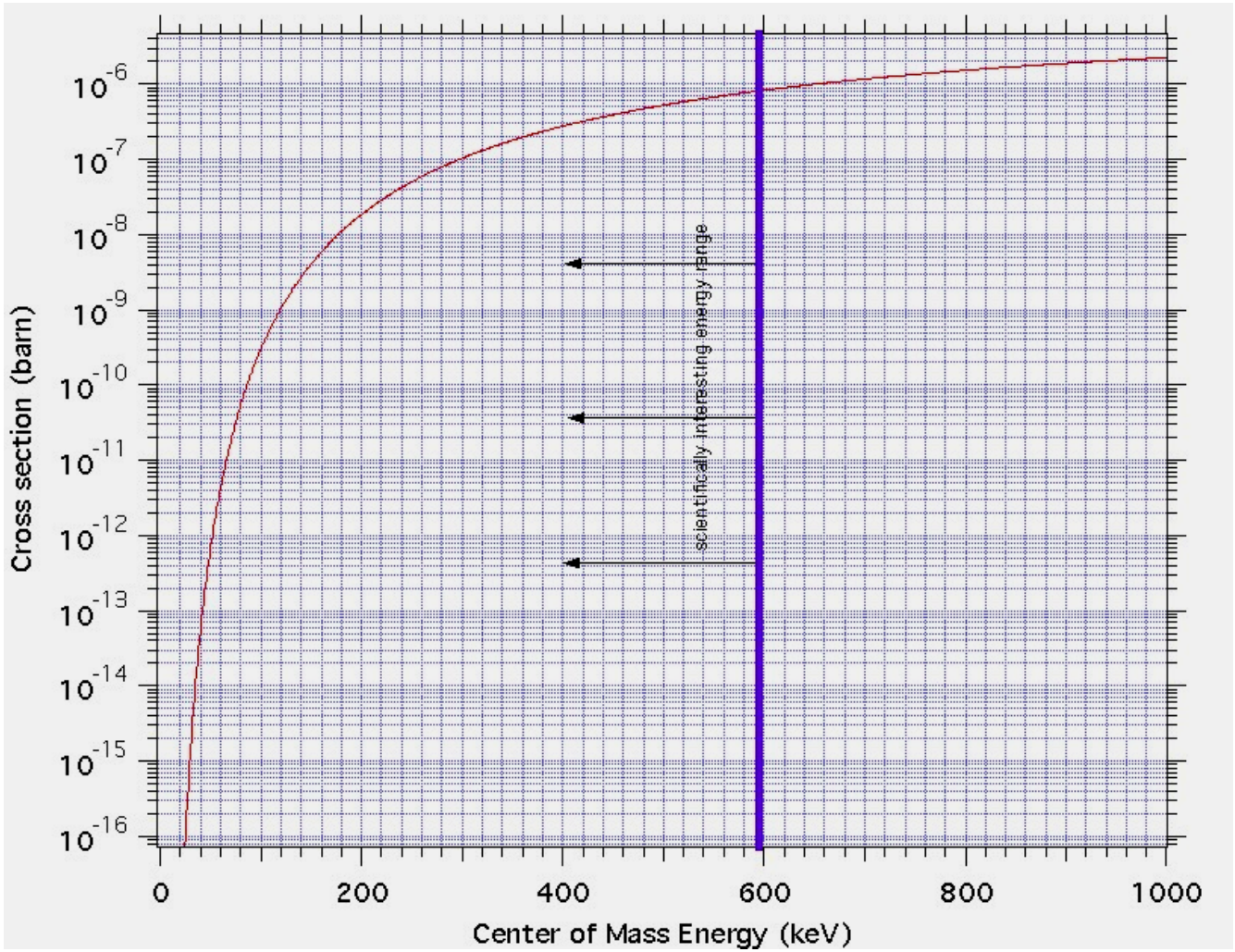

Cross section (barn)
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10^-15
10^-16
0
200
400
600
800
1000
Center of Mass Energy (keV)
Scientifically interesting energy range

Design of a Nuclear Astrophysics Accelerator supported by Laboratory Directed Research and Development (LDRD'06)

Goal

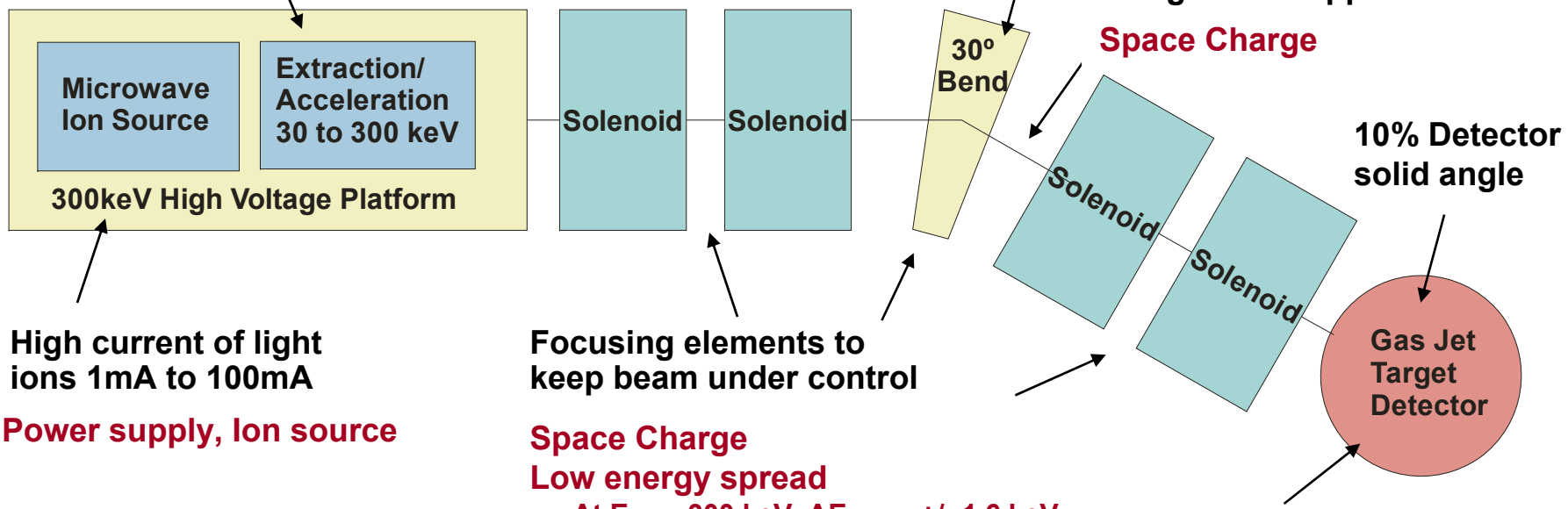
Develop a conceptual design for an unique and versatile astrophysics accelerator with up to two orders of magnitudes higher beam current (100mA, single charged ions) than present state-of-the-art nuclear astrophysics accelerators.

Output/Deliverable of LDRD

Preliminary design of an accelerator and experimental set-up, ready for a funding proposal

First step: Build a set-up at LBNL, which could move underground

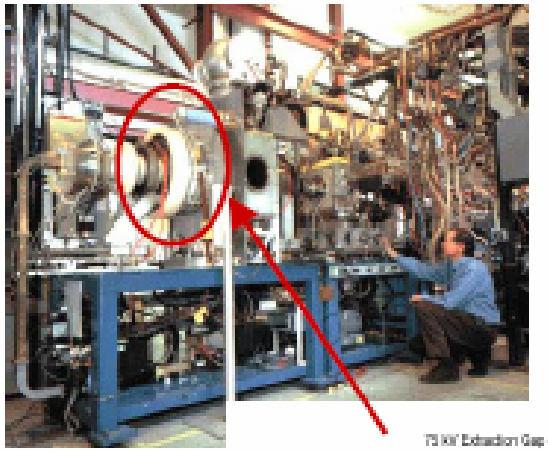
Preliminary Layout and Requirements For the Proposed LBNL Astrophysics Accelerator



Long time stability, Potentially going underground

Single Charged Ion Source, Chalk River Microwave Source

low-energy demonstrator accelerator (LEDA)



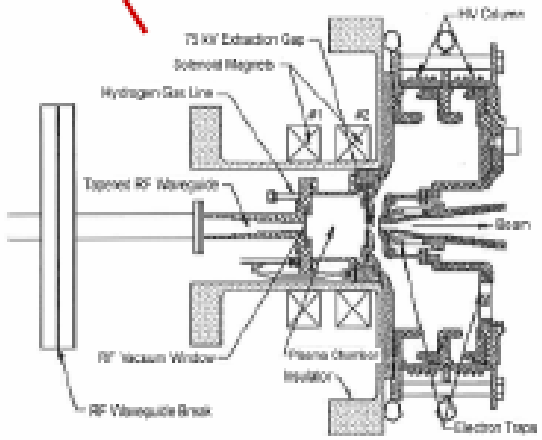
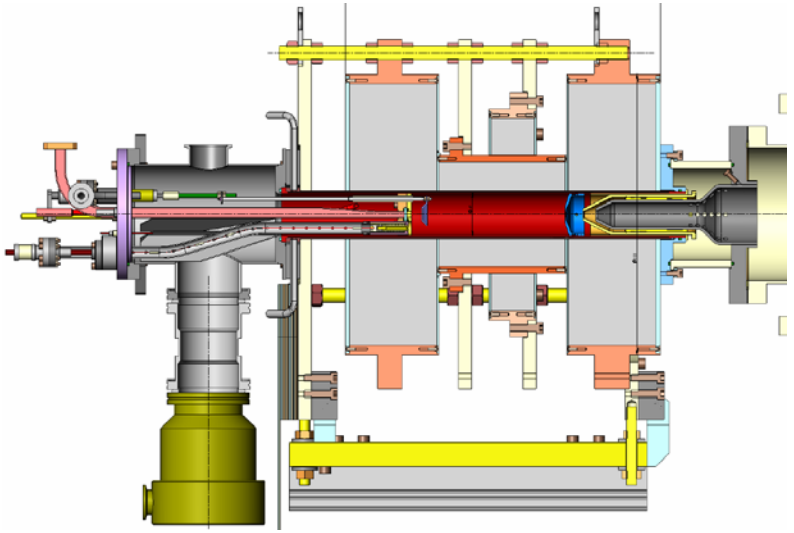


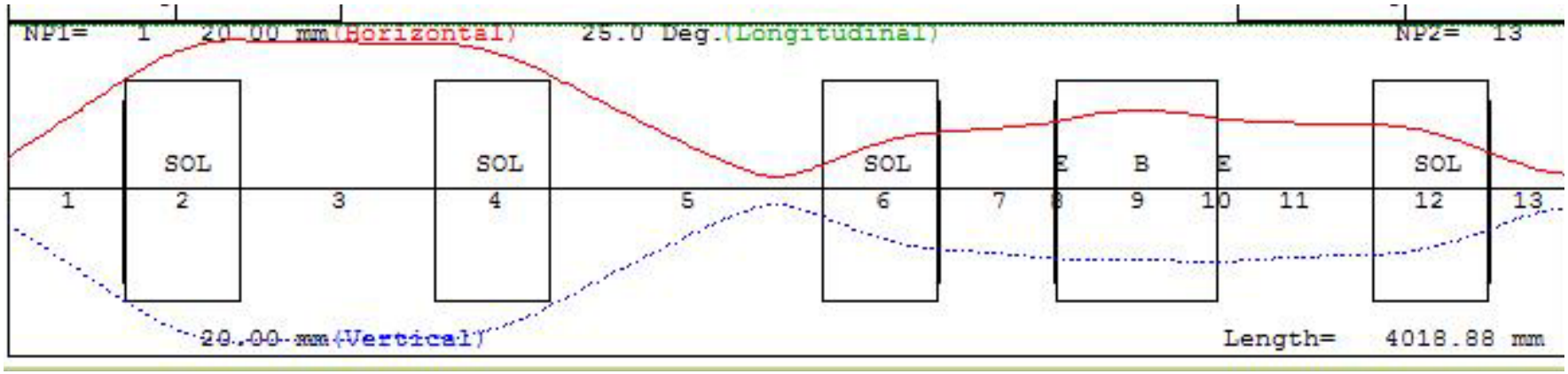
Figure 1. LEDA microwave proton source.



100mA/cm^2
He beams

Multi charged ions
100euA to 1mA

Beam Envelopes through the preliminary beam line



4 Solenoids to add flexibility over the parameter space
End focal point adjustable to provide maximal overlap with gas jet
60 degree bend for good mass resolution
100 mA, ^{3}He, assumption 70% neutralized
(net transported space charge 30mA)

First Parameter List For the Proposed LBNL Astrophysics Accelerator (single charged ions)

Requirements	Issues and Comments
High current of light ions 1mA to 100mA, DC	Energy flexibility while maintaining beam quality
Energy range 25keV to 300 keV	Single charged ions, Chalk River Microwave source
High purity (better than .1%)	High Current Analyzing Magnet
Low energy spread 1%uncertainty At E_{cm} = 300 keV, ΔE_{beam}= +/- 1.6 keV At E_{cm} = 30 keV ΔE_{beam} = +/- 15 eV	Ion Beam Neutralization in the beam line
Gas jet target, 3e17 particles/cm^2 or higher	Engineering, Target density measurement, packaging with beam focus elements and detector system
Energies > 300 keV, low currents 200euA to 1mA	Compact ECR ion source using multi charged ions.

UNDERGROUND LABS and SPACE

- 3000 ft should be sufficient (not evaluated yet)
- Space L x W x H (m^3) 30x30x10, office/lab environment
- Start as early as 2010 (depending on the funding)
- Power: ~600kW (possible some uninterrupted)
- 24/7 operation, experimental campaigns several months
- DI Water, cooling for power supplies
- Humidity controlled or high pressure voltage tank
- Compressed gas, Cylinder gas, HV, cryogenics, microwave equipment
- Some storage space
- Limited mechanical and electrical shop capacity
- Ethernet, Surface counting shack

- **Nuclear Astrophysics Accelerator at LBNL**
  - **up to two orders of magnitudes higher beam current than present state-of-the-art**
  - **Energy Range 25 keV to 300 keV (single charged ions) at >10 mA currents**
  - **Higher Energies with multi charged ions, but less than 1mA current**
  - **State of the art gas jet target**
  - **First Experiment: $^{3}He(^{4}He, \gamma)^{7}Be$**
  - **Build at LBNL, but with the option of moving it underground**